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Field Trial of 300Gb/s 12-Channel Medium Wavelength-Division Multiplexing in Deployed 5G C-RAN Front-haul Network

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Abstract *We report the first real-time field trial of a 300Gb/s 12-channel medium wavelength-division multiplexing (MWDM) system in a deployed 5G C-RAN front-haul network, achieving 24-hour error-free transmission of bidirectional eCPRI signals over 10-km SSMF with an optical link budget of over 15 dB.*

Introduction

5G front-haul transport network is facing new challenges as the architecture of 5G wireless network is developed from distributed radio access network (D-RAN) to centralized radio access network (C-RAN) [1-3]. Compared with the D-RAN network, many distributed units (DUs) are centralized at one central office based on C-RAN architecture, which has significant advantages of saving machine room, reducing power consumption, supporting collaborative radio, etc. However, the maximum transmission distance between active antenna unit (AAU) and DU will be increased from a few hundred meters to 10 km for the main scenario, resulting in great demand on fibre resources. Furthermore, assuming each 5G base station within 3 AAUs based on 160-MHz spectrum resource, six 25G optical modules should be used in AAUs. Thus, 12 fibres are required for connecting these six duplex modules of one base station by using fibre direct connection solution. The total number of the optical fibres will be further increased to 120 for the medium and large-scale C-RAN architecture typically centralized with 10 base stations.

12-channel wavelength division multiplexing (WDM) technology is a promising way to save fibre resource by using only one fibre to connect a base station. Several WDM schemes have been proposed and widely deployed, including coarse WDM (CWDM) [4], local area network WDM (LAN-WDM) [5-6], and Dense WDM (DWDM) [7]. The DWDM system can support 40 wavelengths and beyond. However, the expensive external modulation laser should be used due to the high dispersion penalty in C-band. The system cost would be further increased if tunable lasers are applied [8]. It is noted that the front-haul transport network is very sensitive to the cost of WDM interface. Thus, O-band WDM solutions are more attractive by using low-cost direct modulation laser (DML) as the fibre dispersion in O-band is relatively low. The 12-channel LAN-WDM system is located at O-band from 1269.23 nm to 1318.35 nm with 800 GHz channel spacing, which has advantage of low dispersion penalty. However, it faces system risk introduced by four-wave mixing (FWM) effect [9]. The 6-wavelength CWDM system from 1260 nm to 1380 nm with 20 nm channel spacing based on low-cost DML has been widely deployed, but it is also limited to support 6 channels. Recently, ITU-T has started a new work item G.owdm2 to push forward a 12-channel WDM technology from 1260 nm to 1380 nm.

In this paper, we propose and demonstrate a 12-channel bidirectional medium WDM (MWDM) system from 1260 nm to 1380 nm with uneven channel spacing. We performed 12-channel 25-Gbps MWDM transceivers by shifting design parameters of the optical grate of the CWDM DML laser at the blue side and the red side, respectively, which can reuse the low-cost and mature industry chain of 25-Gbps 6-wavelength CWDM. Moreover, with the help of uneven channel spacing, the FWM risk is effectively suppressed. To verify the quality of the 12-channel 25-Gbps MWDM system, error-free filed-trial transmission over 10-km G.652.D fibre link with an optical link budget of more than 15 dB is achieved during 24-hour real-time test.

Architecture and Principle of MWDM

As shown in Fig. 1, the architecture of 12-channel bidirectional MWDM system consists of 6 I-temp and 6 C-temp duplex MWDM optical modules at AAU and DU side, respectively, a pair of optical de/multiplexer, and a single fibre between the line sides of the two de/multiplexers. The upstream and downstream WDM signals are bidirectional transported through the fibre. Thus, 12-

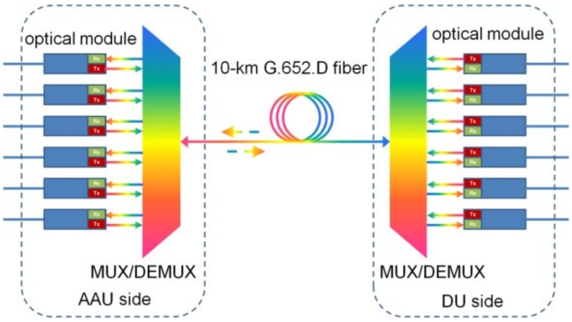

Fig. 1: The architecture of 12-channel bidirectional MWDM system with 300-Gb/s total throughput.

Tab. 1: Central wavelength of CWDM and MWDM channels.

CWDM Channel (nm)	MWDM Channel (nm)	
1271	Channel 0	1267.5
	Channel 1	1274.5
1291	Channel 2	1287.5
	Channel 3	1294.5
1311	Channel 4	1307.5
	Channel 5	1314.5
1331	Channel 6	1327.5
	Channel 7	1334.5
1351	Channel 8	1347.5
	Channel 9	1354.5
1371	Channel 10	1367.5
	Channel 11	1374.5

wavelength WDM lasers are required as the transmitted and received wavelengths of the duplex MWDM module are different.

By adjusting the parameters of the optical grate of the CWDM DML laser, each CWDM channel can be divided into two channels symmetrically with 3.5-nm away from the central wavelength of CWDM. The channel schedules of CWDM and the proposed WDM scheme are shown in Tab.1. The channel spacings between adjacent channels are 7 nm and 13 nm alternatively. The corresponding bandwidth of the filter is reduced to 5 nm. With this uneven channel schedule, not only 12-channel 25-Gbps WDM can be achieved to reuse the matured 6-channels CWDM industry chain but also the FWM risk can be effectively suppressed. As the channel bandwidth of the proposed WDM scheme is between that of coarse WDM and dense WDM, we named it as MWDM. Moreover, CWDM and MWDM have the almost same product technology and process as the internal control requirements of lasers are about ±2.5 and ±2nm, respectively, resulting in similar yield and cost.

Experimental Results

To verify the performance of the proposed 12-channel MWDM system, the real-time experiments and field trial based on the configuration shown in Fig. 1 are carried out. The

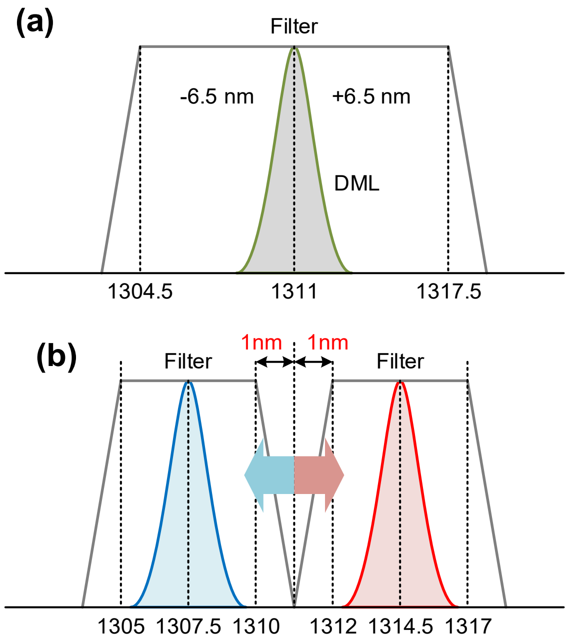

Fig. 2: (a) Wavelength distribution of the CWDM DMLs and (b) Wavelength distribution of the MWDM DMLs.

field trial setups are shown in Fig. 3(g). Here, 25-Gbps eCPRI signals are transmitted from 6 MWDM transceivers and then multiplexed by a WDM multiplexer at AAU side. After transmission over a deployed 10-km G.652.D fibre link, the WDM signal is further demultiplexed by a WDM demultiplexer and received by another 6 MWDM transceivers at DU side. Meanwhile, 6 25Gbps eCPRI signals are transmitted from DU to AAU.

For the concerned FWM problem, we have also done an experiment with all 6 channels for up-stream direction adjusted to 3.43 THz spacing with each other and co-polarization status. The launch power of each channel is 1 dBm. Figure 3 (h) shows the spectra of the MWDM after 10-km transmission in up-stream direction. No idle frequency as well as transmission penalty caused by FWM can be observed. A similar experiment has also been done on LWDM, of which 0.5 dB receiver sensitivity penalty caused by FWM can be observed [9]. These results prove that MWDM can effectively suppress the FWM effect. The eye-diagrams are then measured. The eye-diagrams of two MWDM transceivers with the central wavelengths of 1274.5 nm and 1374.5 nm at 25 °C, -40 °C, and 85 °C are shown in Fig. 3(a-f). The extinction ratios of the 12-channel transceivers are all measured to be 4.1 dB and beyond.

The transmission performance of the MWDM system is subsequently evaluated. The optical power (Tx) at the transmitter and the sensitivity (Rx) are measured, respectively. As shown in Fig. 3(i), the difference between transmitted power and received sensitivity of the 12 channels are all greater than 15 dB with I-temp modules at 25 °C,

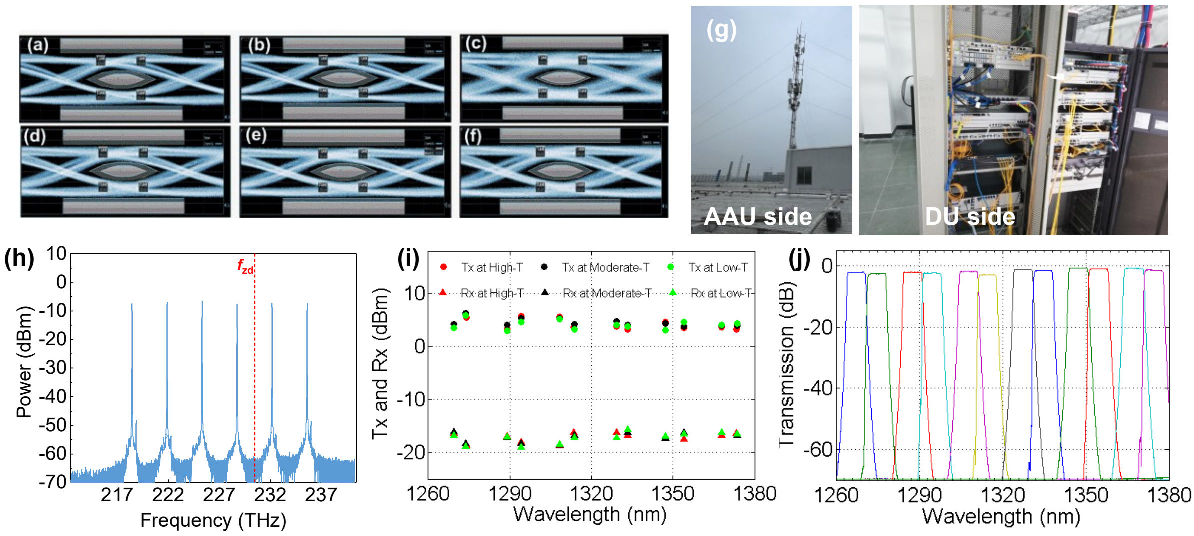

Fig. 3: Eye-diagrams of channel 1 at (a) 25 °C, (b) -40 °C, (c) 85 °C, and channel 11 at (d) 25 °C, (e)-40 °C, -(f) 85 °C, respectively ; (g) Field trial pictures of AAU side and DU side; (h) The spectra of MWDM after 10-km transmission under the condition of co-polarized and aligned-frequencies; (i) Transmitted power and received sensitivity of the 12 channels with different temperature; (j) Spectral response of the 12-channel de/multiplexer.

-40 °C, 85 °C, and C-temp modules at 25 °C, 0 °C, 70 °C, respectively. The results show that the MWDM transceivers are robust to the deteriorated temperature with the help of TEC.

The performance of the MWDM de/multiplexer is further verified. The combined spectral response of the 12-channel de/multiplexer is shown in Fig. 3(j). We can see that the central wavelengths of the adjacent MWDM filters are symmetrical to that of the CWDM filter, indicating that the experimental results are highly consistent with the theoretical analysis.

Error-free field trial transmission of the 12-channel bidirectional MWDM system over 10 km is finally achieved with 24-hour online test, which demonstrated the long-term performance of the MWDM system.

Conclusions

In conclusion, a 12-channel bidirectional MWDM system has been demonstrated. By adjusting the parameters of the optical grating of the CWDM DML laser, 12-channel 25-Gbps MWDM lasers can be cost-effectively obtained. The FWM risk in O-band can be effectively suppressed in MWDM system with uneven channel spacing. Error-free field trial transmission of a 300Gb/s 12-channel MWDM system over 10 km with an optical link budget of over 15 dB has been achieved for the first time to the best of our knowledge, showing the promise of the MWDM technology with both high performance and high cost-effectiveness.

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